(12) UK Patent Application (19) GB (11) 2 215 898 (13) A

(43) Date of A publication 27.09.1989

(21) Application No 8901509.3

(22) Date of filing 24.01.1989

(30) Priority data
(31) 312886 (32) 08.02.1988 (33) DD

(51) INT CL⁴
G09F 9/35, G02F 1/13

(52) UK CL (Edition J)
G5C CA342 CHG

(56) Documents cited
None

(58) Field of search
UK CL (Edition J) G5C CHA CHG CHX
INT CL⁴ G09F, G09G

(71) Applicant
VEB Carl Zeiss Jena

(Incorporated in the German Democratic Republic)

1 Carl-Zeiss-Strasse, Jena, GDR-6900, German Democratic Republic

(72) Inventors
Michael Keil
Dorith Schmidt
Rüdiger Salomon

(74) Agent and/or Address for Service
W P Thompson & Co
Coopers Building, Church Street, Liverpool, L1 3AB, United Kingdom

(54) LC Displays

(57) In an LC display device comprising transparent electrodes 2a, 2b, orientation layers 3, the LC material is of the ferro-electric-smectic type and a linearly polarised light from source 5 is introduced laterally into a rear glass plate 1a and emerges via a light scattering layer 6 on a front glass plate 1b whereby the device is operable independent of ambient light or visual angle, has high resolution capability, short switching times and low temperature dependency. Incident light 8 is either totally internally reflected or refracted in dependence upon the absence or presence of an applied electric field which alters the refractive index at the interface between orientation layer 3 and LC material 4. Instead of a separate layer 6, the surface of plate 1b may be roughened to provide the scattering. The display may be of the segment or matrix type.

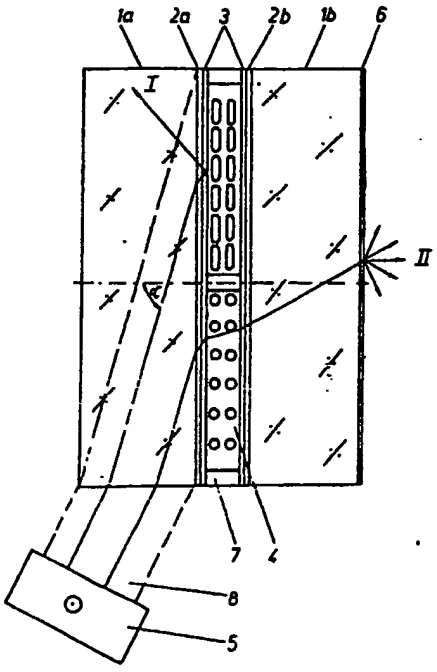

Fig. 1

GB 2 215 898 A

using which information can be displayed, independently of the ambient light, in high contrast and independently of the visual angle, and which is characterised by a high resolution capability, low temperature dependency and short switching times.

The invention is described further hereinafter, by way of example only, with reference to the accompanying drawing which shows the schematic structure of one embodiment of a display element in accordance with the present invention.

An active display element based on the liquid-crystal effect has the following known layer structure: a glass plate 1a - transparent electrodes 2a - orientation layer 3 - liquid crystal 4 - orientation layer - transparent electrodes 2b - glass plate 1b. In order to form a matrix, the transparnt electrodes 2a and 2b are strip-shaped and disposed perpendicularly to one another. The display element also comprises an illuminating device 5 for laterally radiating linearly polarized light 8 into the glass plate 1a and is further characterised in that the liquid crystal is a ferroelectric-smectic liquid crystal 4 and a light-scattering layer 6 is disposed on the side of the liquid-crystal cell facing the observer. The ferroelectric-smectic liquid crystal 4 is orientated in

such a way that, in the optically closed state, the longitudinal axes of the molecules are perpendicular to the polarization direction of the light 8 introduced.

The function of the display element is based on the principle of controllable total reflection utilising an electrically induced alteration in the refractive index. The illuminating device 5 is set so that the polarised light falls on one side into the glass plate 1a and irradiates the entire interface between the orientaticn layer 3 and the liquid crystal 4. The orientation layers 3, whch are made of SiO, lead to a defined initial orientation, in which the longitudinal axes of the molecules of the liquid crystal 4 are perpendicular to the polarisation direction of the introduced light 8 (corresponds to refractive index n_o). Excitation using an electrical field reorientates the liquid-crystal molecules, which results in an alteration of the refractive index to the value n_e. The light introduction angle α is selected such that, in the initial conditiion, that is given n_o, it is slightly above the limiting angle of the total reflection β at the orientation layer 3/liquid crystal 4 interface, and the light beam is reflected in total in accordance with the beam course 1. Reorientation produces n_e of the liquid crystal 4. Since $n_e > n_o$, the limiting angle of total reflection β at the above-mentioned interface

increases, so that the light introduction angle α is then below this limiting angle and the light beam is refracted into the liquid crystal 4 in accordance with the beam course II, and is subsequently scattered through the light-scattering layer 6 in all directions of the half-space in front of the glass plate 1b. The glass plate 1b may itself be light-scattering by virtue of increased surface roughness or other methods, as a result of which the light-scattering layer 6 may be omitted.

The thickness of the liquid-crystal layer 4 is 2 µm and is adjusted by spacers 7. In the case of large-area display elements, it is preferable to dispose the spacers 7 not only on the periphery of the component, but aso in the middle. In order to prevent these spacers 7 leading to interfering light points on the display if their dimensions are too large, low-refracting material is used in order for total reflection to take place at these points.

For the operation mode,it would be ideal to use a ferroelectric-smectic liquid crystal 4 having a theoretical tilt angle of 45^{o}. The ferroelectric-smectic liquid crystal 4 used, which has a tilt angle of less than 45^{o}, means that, in the excited state, only part of the polarized light 8 introduced is refracted

into the liquid crystal 4 and imaged on the display. The other part of the introduced polarized light 8 is reflected, in the optically closed state, at the orientation layer 3/liquid crystal 4 interface. This results only in a reduction in intensity of the information imaged; operation is not impaired. In the embodiment described, the materials listed in Table 1 were used for the various elements.

Table 1

Element	Material	Refractive Index
Glass plates 1a, b	BK 7	1.52
Transparent electrodes 2a, b	ITO	2.00
Orientation layer 3	SiO	1.90
Liquid crystal 4	Ferroelectric-smectic phase	1.455/1.625
Spacers 7	SiO_2	1.44

The display element described can be used in a large variety of fields to display information by realising segment, full or matrix displays. The specific advantages of the invention are to be found above all in its active character, as a result of which the display is not dependent upon ambient light, and in its improved image quality, which is characterised by a high resolution capability, as well as in the very short switching times and in the high multiplex rate. As a

result, large-area display elements are made possible. The active ferroelectric-smectic display element is further characterised by its technologically simple construction and inexpensive production. A further substantial advantage of the display element in accordance with the invention is that no fluctuations in contrast in the information displayed occur as a result of existing inhomogeneities in layer thickness.

CLAIMS

1. An active display element based on the liquid-crystal effect, comprising a liquid-crystal cell having the following construction: glass plate - transparent electrodes, in the form of a segment, full or matrix display - orientation layer - liquid crystal - orientation layer - transparent electrodes - glass plate, and wherein the display element includes an illuminating device for laterally introducing linearly polarized light into a rear glass plate remote from an observer side of the element the liquid crystal is a ferroelectric-smectic liquid crystal and a light-scattering layer is disposed on the side of the liquid-crystal cell facing the observer.

2. A display element as claimed in claim 1, wherein the ferroelectric-smectic liquid crystal is orientated in such a way that, in its optically closed state, the longitudinal axes of the molecules are perpendicular to the polarization direction of the light introduced.

3. An active display element, substantially as hereinbefore described with reference to and as illustrated in the accompanying drawing.

Published 1989 at The Patent Office, State House, 66/71 High Holborn, London WC1R 4TP. Further copies may be obtained from The Patent Office. Sales Branch, St Mary Cray, Orpington, Kent BR5 3RD. Printed by Multiplex techniques ltd, St Mary Cray, Kent, Con. 1/87